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(21) International Application Number: PCT/US92/08470 (22) International Filing Date: 5 October 1992 (05.10.92) (30) Priority data: 770,581 3 October 1991 (03.10.91) US (71) Applicant: INDIANA UNIVERSITY FOUNDATION [US/US]; Showalter House, P.O. Box 500, Bloomington, IN 47402 (US). (72) Inventors: BENSON, Merrill, D. ; 8510 Silver Leaf Court, Indianapolis, IN 46278 (US). MURRELL, Jill ; 3678 Mission Drive, Indianapolis, IN 46224 (US). FARLOW, Martin ; 5049 Potters Pike, Indianapolis, IN 46234 (US). GHETTI, Bernardino ; 1124 Frederick South Drive, In- dianapolis, IN 46260 (US).		(74) Agents: HENRY, Thomas, Q. et al.; Woodard, Emhardt, Naughton, Moriarty & McNett, Bank One Center/Tow- er, Suite 3700, 111 Monument Circle, Indianapolis, IN 46204 (US). (81) Designated States: AU, BB, BG, BR, CA, CS, FI, HU, JP, KP, KR, LK, MG, MN, MW, NO, PL, RO, RU, SD, Eu- ropean patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG). Published <i>With international search report.</i>

(54) Title: METHOD FOR SCREENING FOR ALZHEIMER'S DISEASE

ccaaatgtccccgtcatttaagaaatgaaattcttctaattgcgtttataaattgta

1840
|
aattatattgcatttagaaattaaaattctttttcttaatttgtttcaag GTG TTC
Val Phe
614

TTT GCA GAA GAT GTG GGT TCA AAC AAA GGT GCA ATC ATT GGA CTC
Phe Ala Glu Asp Val Gly Ser Asn Lys Gly Ala Ile Ile Gly Leu

ATG GTG GGC GGT GTT GTC ATA GCG ACA GTG ATC T
GTC
Val
Phe ATC ACC TTG
Met Val Gly Gly Val Val Ile Ala Thr Val Ile Val Ile Thr Leu

GTG ATG CTG AAG AAG AAA CAG TAC ACA TCC ATT CAT CAT GGT GTG
Val Met Leu Lys Lys Lys Gln Tyr Thr Ser Ile His His Gly Val

1986
|
GTG GAG gtaggtaaacttgactgcatgtttccaagtgggaattaagactatgagag
Val Glu
669

(57) Abstract

Methods for screening for risk of Alzheimer's disease involve assaying for a guanine to thymine substitution at position 1924 of the gene encoding the human amyloid precursor protein. Also described are transgenic mammals harboring an expressible gene sequence encoding human amyloid precursor protein having a phenylalanine for valine amino acid substitution in the transmembrane domain of the amyloid precursor protein.

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METHOD FOR SCREENING FOR ALZHEIMER'S DISEASE

BACKGROUND OF THE INVENTION

The present invention relates to a method for screening for risk of Alzheimer's disease in a patient, and to a
5 transgenic mammal carrying a mutated human gene associated with the development of Alzheimer's disease.

Alzheimer's disease is a form of localized amyloidosis characterized by cerebral cortical amyloid plaques, neurofibrillary tangles, and amyloid deposits within the
10 walls of leptomeningeal vessels. Although most cases of Alzheimer's disease are sporadic, kindreds with autosomal dominant inheritance of the syndrome suggest that a single mutation may be important in pathogenesis.

Hereditary or familial Alzheimer's disease is an
15 autosomal dominant form of localized amyloidosis. Patients with hereditary Alzheimer's disease typically develop three pathologic lesions: (i) senile plaques in the cerebral cortex characterized by a central amyloid core surrounded by dystrophic neurites; (ii) neurofibrillary tangles; and (iii)
20 congophilic angiopathy of the leptomeningeal vessels. The amyloid deposits in the senile plaques and in the blood vessel walls contain a fibril subunit protein of 39 to 43 amino acid residues [See, G. G. Glenner and C. W. Wong, Biochem. Biophys. Res. Commun., 120, p. 885 (1984)], which
25 is a portion of the carboxyl terminus of the amyloid precursor protein (APP). Sequence analysis of cDNA clones of APP has shown that there are multiple forms of mRNA which are the result of alternate splicing of a transcript from a single gene. See, J. Kang et al., Nature, 325, p. 733
30 (1987); P. Ponte et al., Ibid, 331, p. 525 (1988); R. E. Tanzi et al., Ibid, p. 528; N. Kitaguchi, Y. Takahashi, Y. Tokushima, S. Shiojiri, H. Ito, Ibid, p. 530; N. Kitaguchi et al., Biochim. Biophys. Acta, 1039, p. 105 (1990); and S. Yoshikai, H. Sasaki, K. Doh-ura, H. Furuya, Y. Sasaki, Gene
35 87, p. 257 (1990). Although the sequence of the APP gene

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from some patients with either sporadic or familial Alzheimer's disease is normal [See, D. Goldgaber, M. I. Lerman, O. W. McBridde, U. Saffotti, D. C. Gajdusek, Science 235, p. 887 (1987); R. E. Tanzi et al., ibid, p. 880; N. K. Robakis, N. Ramakrishna, G. Wolfe, H. M. Wisniewski, Proc. Natl. Acad. Sci. U.S.A., 84, p. 4190 (1987); H. G. Lemaire et al., Nucleic Acids, Res. 17, p. 51 (1989); and M. P. Vitek et al., Mol. Brain Res. 4, p. 121 (1988)], a cytosine to thymine missense mutation in the membrane-spanning domain of the APP gene (causing a valine to isoleucine change in the corresponding amino acid sequence of the encoded APP) has been identified in patients from several families with familial Alzheimer's disease. See, A. Goate et al., Nature 349, p. 704 (1991).

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SUMMARY OF THE INVENTION

In the applicants' work, analysis of DNA from a family with autopsy-proven Alzheimer's disease revealed a single amino acid substitution (phenylalanine for valine) in the transmembrane domain of the amyloid precursor protein. This substitution is caused by a point mutation at nucleotide position 1924 (using the APP695 transcript) of the gene encoding the amyloid precursor protein in which guanine (normal) is replaced by thymine (mutant). This mutation correlated with the presence of Alzheimer's disease in all studied patients. Accordingly, one embodiment of the invention relates to a method for screening for risk of Alzheimer's disease in a patient. The method includes the step of assaying for a guanine to thymine point mutation at position 1924 of the patient's gene encoding the amyloid precursor protein.

The applicants' discovery also provides access to transgenic non-human mammals, preferably rodents such as mice, harboring an expressible gene sequence encoding human amyloid precursor protein having a phenylalanine for valine amino acid substitution in the transmembrane domain of the amyloid precursor protein. Access is also provided to vectors containing the above-noted gene sequence which can be used to create transgenics for study or protein expression (i.e. for production and recovery), and to the above-noted mutant amyloid precursor protein (with the phenylalanine for valine substitution) in substantially pure form.

Additional objects, advantages and embodiments of the invention will be apparent from the following description and appended claims.

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BRIEF DESCRIPTION OF THE FIGURES

Figure 1 sets forth the DNA sequence of a region amplified by PCR (nucleotides 1732 through 2036) (Seq. I.D. No. 1). Lower case letters designate introns; capital letters designate exon 15, which encodes the C-terminal portion of amyloid β -protein, amino acids 614 through 669 (exon 17 if numbered by the APP770 transcript. Solid lines indicate oligonucleotide primers used in the PCR reactions. The mutation at position 1924 is in the box. Solid arrowhead indicates the carboxyl terminus of the longest β -amyloid peptide sequence that has been reported (43 residues).

Figure 2 sets forth an abbreviated pedigree of a family with early onset Alzheimer's disease used in applicants' study. Solid symbols indicate affected individuals. Tissue DNA was studied from all affected individuals in generation II. DNA isolated from peripheral blood leukocytes of III-10 and the five unaffected individuals of generation II was studied. Arrow denotes propositus.

Figure 3 depicts a stained preparation showing neurofibrillary tangles and senile plaques in the subiculum of patient II-11 of the Figure 2 pedigree. In the plaques both a neuritic crown and a prominent amyloid core are seen. The majority of nerve cells contain neurofibrillary tangles. Preparation was stained with DeMyer modification of Hortega silver carbonate method; 250x magnification.

Figure 4 sets forth autoradiographs of sequencing gels of the APP gene exon 15 in affected and unaffected individuals. (A) Positive strand sequence of DNA from peripheral blood. (B) Sequences from formalin fixed brain tissues. Sequencing of the opposite strand confirmed the mutation. Numbering is according to the APP695 transcript.

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DESCRIPTION OF THE PREFERRED EMBODIMENT

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to certain embodiments and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated device, and such further applications of the principles of the invention as described herein being contemplated as would normally occur to one skilled in the art to which the invention relates.

Genomic DNA from three generations of a family with classic early-onset autosomal dominant Alzheimer's disease was used in applicants' study. In particular, exon 15 of the APP gene was amplified and sequenced using the polymerase chain reaction (PCR). See, e.g., H. G. Lemaire et al., Nucleic Acids Res. 17, p. 51 (1989); A. Goate et al. Nature 349, p. 704 (1991); and U. B. Gyllenstein and H. A. Erlich, Proc. Natl. Acad. Sci. U.S.A. 85, p. 7652 (1988). The DNA sequence of a region amplified by PCR is set forth in Fig. 1.

An abbreviated pedigree of the family of the applicants' study is set forth in Fig. 2. Affected members of this family (solid symbols in Fig. 2) show clinical onset of disease with short-term memory problems in their 40's. Other cognitive difficulties develop as the disease gradually progresses. Disease duration is typically 7 years. Postmortem examinations of the brains of three members of generation II (see Fig. 2) showed histologic lesions typical of Alzheimer's disease with only minor vascular amyloid deposits and no evidence of cerebral hemorrhage. See Fig. 3. Individuals II-2, II-6 and II-11 developed dementia at ages 41, 42 and 45 and died at ages 49, 48, and 53, respectively. One individual in generation III is presently 44 years of age and suffers from a severe presenile

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dementia. DNA from the five unaffected members of generation II, who are well beyond the age of expression of disease in this kindred, was also analyzed. As indicated above, in the affected members, the applicants' analysis revealed a point
5 mutation at nucleotide position 1924 of the gene encoding the amyloid precursor protein in which guanine is replaced by thymine. This mutation causes an amino acid substitution (phenylalanine for valine) in the transmembrane domain of the amyloid precursor protein, specifically at amino acid 717
10 (transcript APP₇₇₀), which is two residues down from the carboxy terminus of the β -amyloid peptide (See Fig. 1).

In contrast to linkage analyses that do not show association of Alzheimer's disease with the APP gene [See, R. E. Tanzi et al., Nature 329 p. 156 (1987); C. V. Broeckhoven et al., *ibid*, p. 153; and G. D. Schellenberg et al., Am. J. Hum. Genet. 48, p. 563 (1991)], the occurrence of the mutation
15 in the APP in individuals from two generations of a kindred affected with Alzheimer's disease is evidence for this mutation as the cause of amyloid deposition and dementia.

20 This mutation is consistent with observations of familial amyloidotic polyneuropathy (FAP), in which multiple single amino acid substitutions are associated with amyloid fibril formation. See, M D. Benson and M. R. Wallace, in The Metabol. Basis of Inherited Disease, C. R. Scriver, A. L. Beaudet, W. S. Sly and D. Valle, Eds. (McGraw Hill, ed VI, New York, 1989, p. 2439. Although the pathogenesis of
25 disease in systemic amyloidosis is generally considered to involve the formation of amyloid deposits that lead to destruction of normal tissue, similar conclusions cannot yet
30 be drawn for hereditary Alzheimer's disease. Although the applicants' invention is not bound by any theory, the dementia may be in part the result of altered function of the variant APP protein and not the direct result of displacement
of normal tissue by amyloid fibrils.

35 As indicated, the Val to Phe amino acid substitution is

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two residues beyond the carboxyl terminus of the β -amyloid peptide subunit isolated from fibrils. Single amino acid substitutions are also found in other forms of hereditary amyloidosis. In the transthyretin amyloidoses (FAP, types I and II), a number of single amino acid substitutions in transthyretin are associated with the amyloid syndrome. See, M D. Benson and M. R. Wallace, in The Metabol. Basis of Inherited Disease, C. R. Scriver, A. L. Beaudet, W. S. Sly and D. Valle, Eds. (McGraw Hill, ed VI, New York, 1989, p. 2439. Similarly, FAP type III is associated with amyloid deposits that contain a peptide of apolipoprotein A1 with a single amino acid substitution (Gly to Arg). See, W. C. Nichols, R. E. Gregg, H. B. Brewer, Jr., M. D. Benson, Genomics 8, p. 318 (1990). In Gerstmann-Sträussler-Scheinker disease (GSS), a hereditary adult-onset dementia with cerebral amyloid plaques composed of a fragment of the prion protein, every GSS family studied to date has a mutation in the gene coding for this protein. See, K. Doh-ura, J. Tateiski, H. Sasaki, T. Kitamoto, Y. Sakaki, Biochem. Biophys. Res. Commun., 163, p. 97 (1989); K. Hsiao et al., Nature, 338, p. 342 (1989); and F. Tagliavini et al., EMBO J., 1, p. 513 (1991). Hereditary cerebral hemorrhage with amyloidosis in Icelandic kindreds (HCHWA-I) is associated with a single amino acid substitution in cystatin C [See, J. Ghiso, O. Jensson, B. Frangione, Proc. Natl. Acad. Sci. U.S.A., 83, p. 2974 (1986)], and a similar syndrome in Dutch kindreds (HCHWA-D) is associated with a single amino acid substitution of Gln for Glu in APP. See, E. Levy, et. al., J. Exp. Med. 169, p. 1771 (1989).

As to assaying for the above-mentioned guanine to thymine point mutation, many methods for detecting single base changes in genomic DNA are known and will be suitable for the methods of the present invention. For example, the technique applied need not be direct DNA sequencing, but rather can include an analysis of other materials derived from or caused

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by the point mutation. For instance, methods of detecting single base changes in genomic DNA which are more readily applied than direct DNA sequencing are preferred. As one example, the applicants have employed the PCR-IMRA technique
5 as further detailed in Example 2 below. In any event, the utilization of these and other known techniques in the present invention is within the skill of artisans in the field. Further, genomic DNA can be isolated from any suitable source in the patient (e.g. tissues, blood
10 leukocytes, etc.), and the methods of the invention applied to any individual to be screened, including in prenatal screening procedures.

As indicated above, a further embodiment of the invention relates to a transgenic, non-human mammal, preferably a
15 rodent such as a mouse, harboring an expressable gene sequence encoding human amyloid precursor protein having a phenylalanine for valine amino acid substitution (at amino acid 717, APP₇₇₀ transcript) in the transmembrane domain of the amyloid precursor protein. The gene sequence is
20 introduced, e.g. through an appropriate vector, into the mammal or an ancestor of the mammal at an embryonic stage, preferably at the single-cell stage (i.e. fertilized eggs). The resulting transgenic animal harbors the expressable mutated gene in its somatic and germ cells and may be used in
25 further study of CNS amyloidosis and the effects of the point mutation and potential development of Alzheimer's disease and/or its related symptoms. The creation of transgenics and the related methodologies are well known [see, e.g. U.S. patent No. 4,736,866] and in particular have also been
30 applied to create transgenic rodents expressing normal human APP protein. See, D.O. Wirak et al., "Deposits of Amyloid β Protein in the Central Nervous System of Transgenic Mice," Science, 253, pp. 323-325 (1991); and, D. Quon et al., "Formation of β -amyloid Protein Deposits in Brains of
35 Transgenic Mice," Nature, 352, pp.239-241 (1991). These

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techniques are readily applied in the present invention.

The following examples are illustrative, and not restrictive, of the invention. All publications cited herein are hereby incorporated by reference in their entirety.

EXAMPLE 1
Direct DNA Sequencing

5
Genomic DNA was isolated from tissue specimens or peripheral blood leukocytes. Liver tissue of subjects II-11 had been frozen at the time of autopsy in 1980. Brain tissue
10 from subject II-6 had been fixed in formalin in 1968. For DNA extraction, the cerebellum was used because of the high density of cells. For subject II-2, DNA was extracted from a Congo red-stained histologic section of cerebral cortex. See, W. C. Nichols, R. E. Gregg, H. B. Brewer, M. G. Benson,
15 Genomics, 8, p. 318 (1990).

Direct sequencing of PCR-amplified DNA of patient III-10 showed both a guanine and thymine at position 1924 of APP (see Fig. 4). Thus, the individual was heterozygous with both a normal GTC (valine) and a variant TTC (phenylalanine)
20 codon. Direct sequencing of amplified tissue DNA from the three affected members in generation II showed that each was heterozygous for the point mutation at position 1924. Direct DNA sequencing for the five unaffected generation II siblings who are beyond the usual age of onset of disease revealed
25 only the normal guanine at position 1924. In addition, analysis of DNA from 100 unrelated individuals failed to show this mutation, which suggests this is not a polymorphism that co-segregates with disease by chance.

EXAMPLE 2
NON-ISOTOPIC DNA TEST

30
Total genomic DNA was isolated from either peripheral blood leukocytes when possible [See, D. Goldgaber, M. I. Lerman, O. W. McBride, U. Saffotti, D. C. Gajdusek, Science 235, p. 887 (1987); R. E. Tanzi et al., *ibid*, p. 880; N. K.

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Robakis, N. Ramakrishna, G. Wolfe, H. M. Wisniewski, Prod. Natl. Acad. Sci. U.S.A., 84, p. 4190 (1987)] or formalin fixed tissue sections [See, H. G. Lemaire et al., Nucleic Acids Res. 7, p. 51 (1989)], as described previously, from several generations of the family with classical early-onset familial Alzheimer's disease. Enzymatic amplification was performed in 50 μ M each dNTP (Pharmacia), 0.25 U Amplitag DNA polymerase (Perkin-Elmer Cetus), 0.5 μ h DNA and 150 ng each primers APPEX15-3' and ALZ PCR-IMRA (Table 1). Primer APPEX15-3' anneals to a region near the 3' end of exon 15 of the amyloid β -protein (exon 17 if numbered by the APP770 transcript). Primer ALZ PCR-IMRA was designed to anneal immediately 5' to the site of the G - T mutation site and contains a single mismatch near its 3' end. Amplification of the variant allele with these primers produces a Bgl II site (AGATCT) in the resulting 90 base pair PCR product, while the PCR product derived from the normal allele using the same set of primers contains no Bgl II site (Fig. 1). Amplification was performed using a Perkin-Elmer Thermal Cycler for 35 cycles consisting of denaturing at 94° for 1 minute, primer annealing at 62° for 1 minute and extending at 72° for 1 minute. Following amplification, the reactions were extracted with 100 μ l Sevag and a 10 μ l aliquot was electrophoresed on a 4% composite (3% FMC NuSieve/1% Bethesda Research Labs) agarose gel for 1 hour at 80 V, stained with 1 μ g/ml ethidium bromide and photographed on a UV light source to ensure successful amplification. An additional 10 μ l aliquot of reactions containing a predominant band of the expected size (90bp) was digested with 14 U Bgl II (United States Biochemicals) in 1X supplied HIGH buffer at 37°. After at least 1 hour of digestion, the entire digest was electrophoresed on a 4% composite agarose gel at 80 V for 90 minutes.

RESULTS

Testing was performed on DNA isolated from 4 family

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members known to be heterozygous for the variant allele by direct genomic sequencing and an additional 4 family members shown to be homozygous for the normal allele. DNA from 2 of the positive controls was obtained from formalin fixed brain tissue. DNA from the remainder of the positive controls and all 4 negative controls was isolated from peripheral blood leukocytes. Amplification of all 8 samples yielded a single predominant PCR product of the appropriate size. Digestion of the resulting PCR products revealed an additional 68 bp digestion product in all 4 positive controls, while none of the negative controls showed any evidence of an additional product. Thus, the PCR-IMRA technique can be effectively used to screen for the subject point mutation.

EXAMPLE 3 Transgenic Mammal

The method of D. O. Wirak et al., Science, 253, pp. 323-325, is used to generate a fragment containing the above-identified mutant APP gene having a guanine to thymine point mutation at position 1924. Accordingly, an open reading frame including the mutant APP is contained within a Bgl II-Bam HI restriction fragment and generated by site directed mutagenesis [L. Kunkel et al., Methods Enzymol., 154, 367 (1987)] of APP cDNA sequences with a synthetic oligonucleotide primer (5'-GGTGTGTCATAGCGTAGGATCCGTCATCACCTTGGTG-3'). This Bgl II-Bam HI restriction fragment is ligated into the Bam HI site of pMTI-2307 [D. O. Wirak et al., EMBO J., 10, 289 (1991)] to generate inventive fragment 1 ("IF1"). An -2-kb Bam HI restriction fragment, containing APP 695 3'-end cDNA sequences, is inserted into the Bam HI site of IF1 to generate IF2. An 0.6-kb Sph I restriction fragment of pMTI-2304, containing SV40 RNA splicing signals [H. Okavama and P. Berg, Mol. Cell. Bull., 3, 280 (1983)] and SV40 viral DNA is ligated into a Sph I site of IF2 to generate IF3. A

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Not I restriction fragment of IF3 is used (in the method of D. O. Wirak et al., EMBO J., supra) to produce a transgenic mouse. This mouse thus harbors an expressable gene sequence encoding a mutant human amyloid precursor protein which has a
5 valine to phenylalanine amino acid substitution at amino acid position 717 (transcript APP₇₇₀) in the transmembrane domain of the amyloid precursor protein.

While the invention has been described in detail in the Figures and foregoing description, the same is to be
10 considered as illustrative and not restrictive in character, it being understood that only the preferred embodiment has been described and that all changes and modifications that come within the spirit of the invention are desired to be protected.

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(1) General Information

- (i) Applicant: Merrill D. Benson, Jill Murrel and Martin Farlow
- (ii) Title of Invention: Method For Screening For Alzheimer's Disease
- (iii) Number of Sequences: 1
- (iv) Correspondence Address:
- (A) Addressee: Thomas Q. Henry
- (B) Street: Bank One Tower, Suite 3700,
111 Monument Circle
- (C) City: Indianapolis
- (D) State: Indiana
- (E) Country: USA
- (F) Zip: 46204
- (v) Computer Readable Form:
- (A) Medium Type: Diskette, 3.50 inch, 1.4 Mb storage
- (B) Computer: COMPAQ
- (C) Operating System: MSDOS
- (D) Software: ASCII
- (vi) Current Application Data:
- (A) Application Number: 07/770,581
- (B) Filing Date: October 3, 1991
- (C) Classification: 2
- (vii) Prior Application Data: NONE
- (viii) Attorney Information:
- (A) Name: Thomas Q. Henry
- (B) Registration Number: 28,309
- (C) Reference/Docket Number: IU-14
- (ix) Telecommunication Information
- (A) Telephone: (317) 634-3456
- (B) Telefax: (317) 637-7561
- (2) Information for Seq. ID No. 1
- (i) Sequence Characteristics
- (A) Length: 305 base pairs
- (B) Type: Nucleic Acid
- (C) Strandedness: Single
- (D) TOpology: Linear
- (ii) Molecule Type: Genomic DNA

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(xi) Sequence Description: SEQ ID NO:1:

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	AATTGTAAAT TATATTGCAT TTAGAAATTA AAATTCTTTT TCTTAATTTG	100
5	TTTTCAAG GTC TTC TTT GCA GAA GAT GTG GGT TCA AAC AAA GGT Val Phe Phe Ala Glu Asp Val Gly Ser Asn Lys Gly 1 5 10	144
	GCA ATC ATT GGA CTC ATC GTG GCC GGT GTT GTC ATA GCG ACA GTG Ala Ile Ile Gly Leu Met Val Gly Gly Val Val Ile Ala Thr Val 15 20 25	189
10	ATC TTC ATC ACC TTG GTG ATG CTC AAC AAG AAA CAG TAC ACA TCC Ile Phe Ile Thr Leu Val Met Leu Lys Lys Lys Gln Tyr Thr Ser 30 35 40	234
15	ATT CAT CAT GGT GTG GTG GAG GTAGGTAAAC TTGACTGCAT Ile His His Gly Val Val Glu 45	275
	GTTTCCAAGT GGGAATTAAG ACTATGAGAG	305

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What is claimed is:

1. A method for screening for risk of Alzheimer's disease in a patient, comprising the step of assaying for a guanine to thymine point mutation at position 1924 of the patient's gene encoding the amyloid precursor protein.
5
2. The method of claim 1 also including the steps of: isolating genomic DNA including said position 1924; and sequencing said DNA to determine whether or not it has said point mutation.
- 10 3. The method of claim 2 wherein said sequencing includes direct DNA sequencing.
4. The method of claim 1 wherein said assaying includes non-isotopic DNA assaying.
- 15 5. The method of claim 4 in which said DNA is isolated from peripheral blood leucocytes of the patient.
6. A transgenic non-human mammal harboring an expressable gene sequence encoding human amyloid precursor protein having a valine to phenylalanine amino acid substitution at amino acid position 717 (transcript APP₇₇₀)
20 in the transmembrane domain of the amyloid precursor protein.
7. The mammal of claim 6 which is a rodent.
8. The mammal of claim 6 wherein the valine to phenylalanine amino acid substitution is caused by a guanine to thymine substitution in the codon for said amino acid.
- 25 9. The mammal of claim 7 which is a mouse.
10. The mammal of claim 8 which is a mouse.

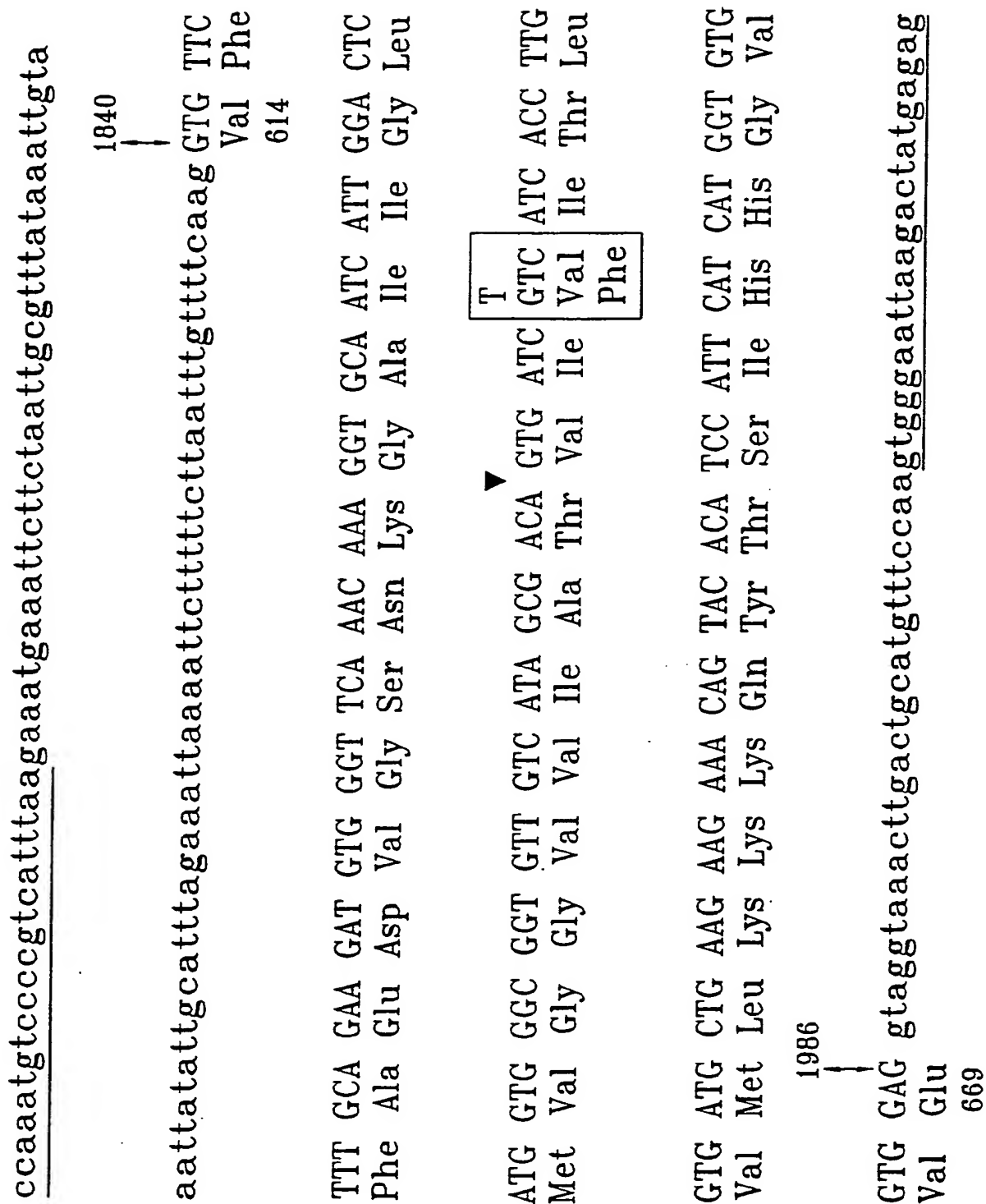


Fig. 1

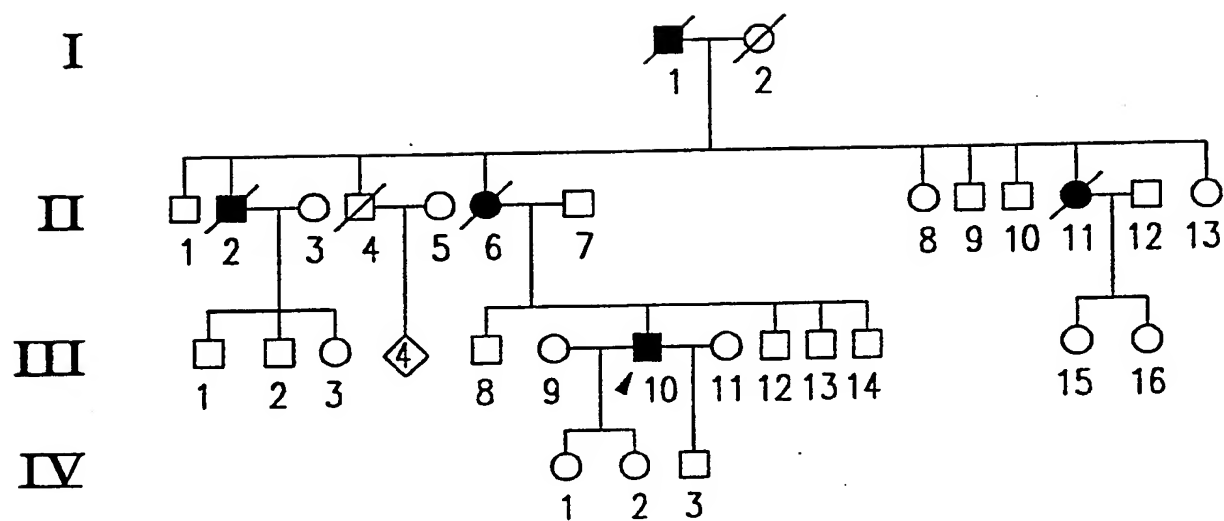


Fig. 2

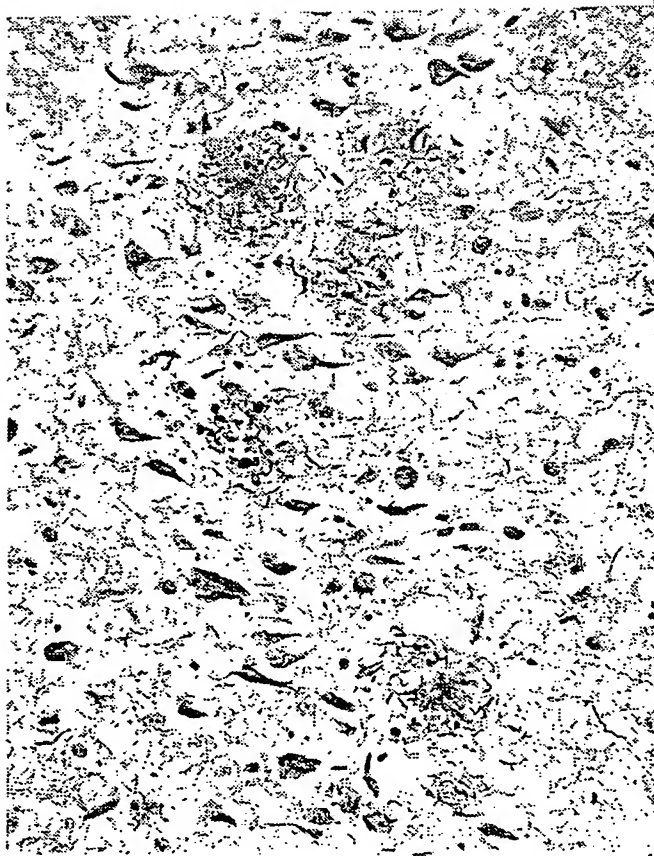


Fig. 3

SUBSTITUTE SHEET

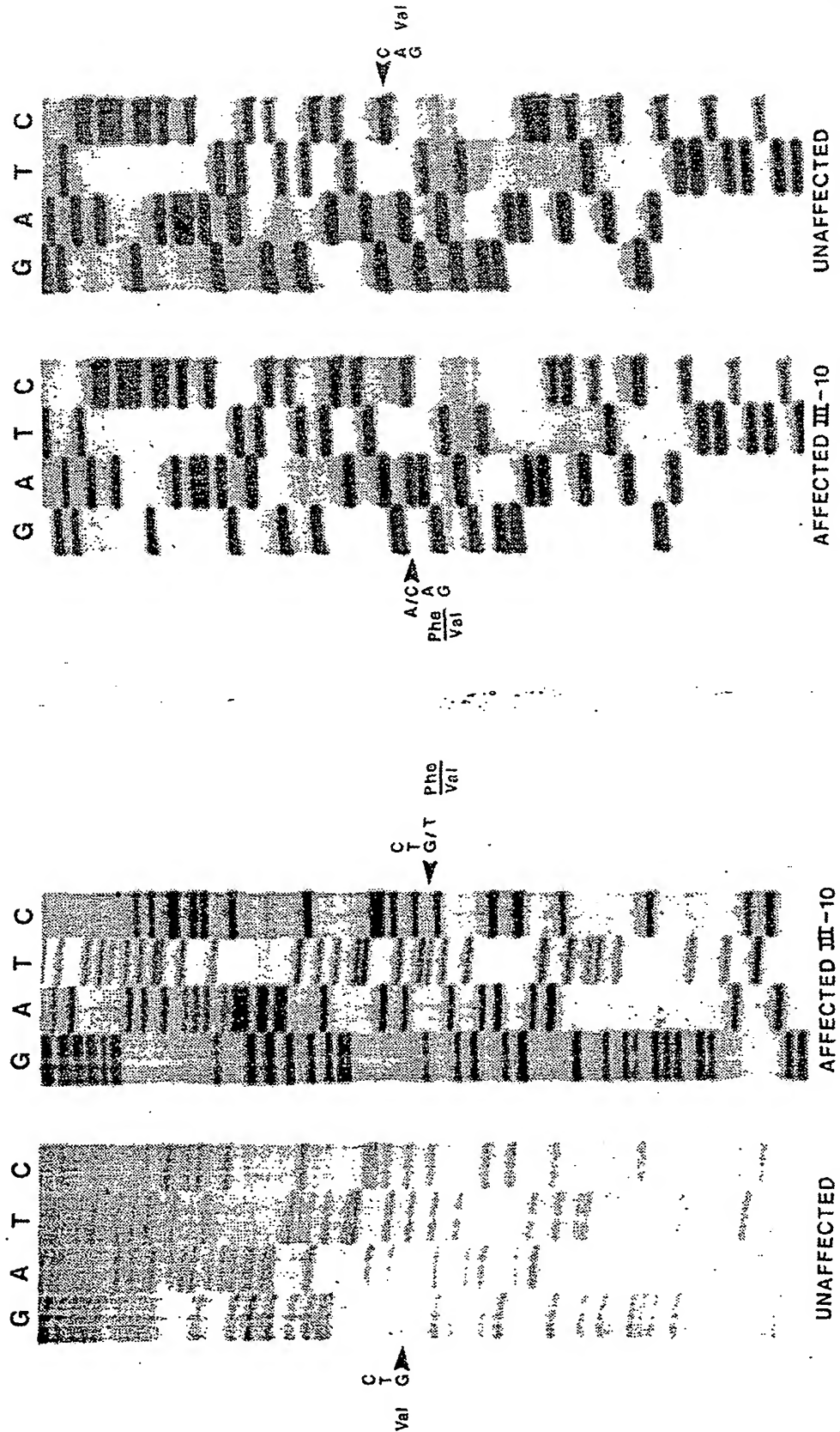


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/08470

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : C12Q 1/68; C12P 19/34; C07H 15/12, 17/00; C12N 15/00

US CL : 435/6, 91; 536/27; 935/77, 78; 800/2

According to International Patent Classification (IPC) r to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/6, 91; 536/27; 935/77, 78; 800/2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS and Chemical Abstracts

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Nature, Volume 349, issued 21 February 1991, A. Goate et al, "Segregation of a Missense Mutation in the Amyloid Precursor Protein Gene with Familial Alzheimer's Disease", pages 704-706, especially abstract and 705, col. 2 parag. 2 to page 706, col. 1, line 2.	1-10
Y	Science, Volume 253, issued 19 July 1991, D. O. Wirak et al, "Deposits of Amyloid B Protein in the Central Nervous System of Transgenic Mice", pages 323-325, see entire document.	6-10
Y	Nature, Volume 352, issued 18 July 1991, D. Quon et al, "Formation of β -Amyloid Protein Deposits in Brains of Transgenic Mice", pages 239-241, see entire document.	6-10
Y	US,A, 4,965,190 (WOO ET AL) 23 October 1990, see col. 6, line 41 to line 68.	1-5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search

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